KES Transactions on Sustainable Design and Manufacturing II
Sustainable Design and Manufacturing 2015 : pp.644-655 : Paper sdm15-047

Supply Chain Re-shoring and its Relationship with Supply Chain Resilience

Anthony Soroka[1], Mohamed Naim[1], Laura Purvis[1], Andrew Hopkins[2]

[1]Cardiff Business School, Cardiff University, Aberconway Building, Colum Drive, Cardiff, CF10 3EU, UK
SorokaAJ@cardiff.ac.uk, NaimMM@cardiff.ac.uk, PurvisL@cardiff.ac.uk

[2]Cardiff School of Engineering, Cardiff University, Queen's Buildings, The Parade, Cardiff, CF24 3AA, UK
HopkinsAC2@cardiff.ac.uk

Abstract *Global manufacturing supply chains are facing numerous challenges that increase complexity and vulnerability to disturbances, therefore, to survive, supply chains must be resilient. In order to meet some of these challenges companies are also reversing off-shoring decisions. This work observes that some of the factors driving re-shoring also have synergy with resilience, yet this relationship has not been studied in great depth. This conceptual paper examines some of the factors driving the re-shoring of manufacturing (including creating a definition of re-shoring suitable for the UK) and the capabilities that create supply chain resilience. A mapping exercise is conducted that explains the synergy between re-shoring and resilience. It suggests that re-shoring helps build a more resilient supply chain.*

1. Introduction

There is a considerable amount of literature that examines the advantages and disadvantages of global versus domestic sourcing and production [1]. Global sourcing practises, for example, have been linked to the speculation concept, securing products at the earliest possible time and holding inventories until the products are sold to retailers. In a similar context, domestic sourcing is related to the postponement principle. That is, the delay in product differentiation happens nearer to the retailers' selling point.

Recently, both academics and practitioners have been reporting on the trend of re-shoring, also referred to as back-shoring [2]. A significant proportion of the academic work analysing the trend of re-shoring, and producing definitions for the concept, has been based around countries such as the US [3] and Germany [4]. Manufacturing in the UK has some differences to the economies that have been examined in these studies, in that major global companies are based within these two countries - in the FT500 rankings for the automotive and parts sectors [5] four of the five biggest companies (in terms of turnover) are US or German. In contrast, a significant proportion of what are considered to be quintessentially British brands

are foreign owned [6] including examples such as: Bentley, Cadbury, Jaguar and Land Rover. Due to this, the issue of country becomes particularly sensitive when considering and applying definitions of re-shoring to the UK, especially when definitions of re-shoring refer to the country of the parent company as in [3].

Supply chain (SC) resilience is still considered to be an emerging field within the area of supply chain management (SCM) and is essentially defined as being "the ability of a [supply chain] to return to its original state or move to a new, more desirable state after being disturbed" [7]. Sheffi and Rice [8] suggested that resilience is "the ability to bounce back from a disruption" without necessarily moving to a new state, while Ponomarov and Holcomb [9] considered it to be the ability of the SC to prepare, respond and recover from disruptions.

Martineau [10] and Bailey and De Propris [11] suggested that SC resilience is a factor in the re-shoring decision making process. However, it is of note that in [10] the term "SC resilience security of supply" is used in the UK industry survey which [11] references. This begs the question: were respondents to the survey considering SC resilience, SC security or both? It also raises the more challenging question of what is the nature of the relationship between SC re-shoring and resilience and will re-shoring help build a resilient SC. The paper conducts an exploratory study to examine the links between re-shoring and resilience that appear in SCM literature. One research question is tackled: "What relationship is there between the factors driving re-shoring decisions and those for resilience".

A review of literature, as identified through bibliographic databases, that describe research on companies who have re-shored or have examined SC resilience has been conducted. Based upon this the primary factors driving re-shoring, creating SC vulnerabilities and creating SC resilience have been identified. Using these results a mapping study was undertaken to examine the links between re-shoring and SC resilience.

2. Re-shoring

Traditionally global sourcing lowers production costs, through low wages / employment costs and economies of scale, but recent studies are suggesting that companies are finding it less cost effective [3]. Due to the high demand uncertainty characteristic of industries, for example, such as electronics manufacturing, maintaining speculative inventories, especially in the form of finished goods, may incur high holding and obsolescence costs. Global sourcing may also result in poor customer service due to slow, or lack of, replenishment [12]. Domestic sourcing can lower total inventory costs and increase customer service by reducing the time-to-serve and improving replenishment rates, but it can incur higher production

costs [13]. At the same time, the decision to manufacture closer or further to the headquarter and / or the customer needs to be continuously reconsidered, as the balance of costs and time to market can change dramatically at very short notice, calling for the re-design of the SC and the re-distribution of production activities across the world [14],[15]. Therefore there are a number of important factors that need to be considered when making sourcing decisions.

It has been observed [16] that although there have been numerous companies announcing the return of all or part of their off-shored production, academic attention has lagged behind, which is characterised by a lack of shared definition. This is further exacerbated by multiple theoretical concepts being used to define similar concepts as is shown in [16] including the use of terms such as re-shoring, back-shoring and near-shoring.

Holz [17] in 2009 defined back-shoring as being "The geographic relocation of a functional, value creating operation from a location abroad back to the domestic country of the company". This study focused on the activities of the German automotive industry and their off-shoring and subsequent back-shoring activities.

Also in 2009 Kinkel and Maloca [4] created the definition that back-shoring is "Re-concentration of parts of production from own foreign locations as well as from foreign suppliers to the domestic production site of the company". As with [17] this article focused on German industry. However, its industrial focus was very broad encompassing 14 sectors in total ranging from food and textiles to electrical machinery and transportation equipment.

Sirkin [18] in a 2012 study on seven sectors of US manufacturing is paraphrased by Gray [3] as stating that re-shoring is bringing "manufacturing back home to where the majority of demand lies".

In a special issue of the Journal of Supply Chain Management in 2013 Gray [3] and Ellram [1] define re-shoring as "Moving manufacturing back to the country of its parent company". Ellram also expanded on the idea of re-shoring "… whereas near-shoring refers to locating a manufacturing plant within one's region".

In [3] whilst discussing the concept of re-shoring, it is noted that the term "off-shoring", of which re-shoring is a reversal, is imprecise, in that sourcing from China, to meet US demand, would be off-shoring but it is less clear as to whether the same is true for Canada or Mexico. This means that there is potential for some degree of ambiguity as to what the term "Country" may mean within a definition. The other definitions suggest that the country of a company may refer to: Location of a company's headquarters, where a company is listed on the stock exchange,

where a wholly / partially owned business unit of a multinational company is located.

This ambiguity is exacerbated within the UK which is made up of three countries England, Scotland and Wales and one province Northern Ireland. Where the decision of a company based in Wales to re-shore manufacturing to England from China could be considered both re-shoring, from the English / British / UK perspective,) and near-shoring from the Welsh perspective.

The situation is further complicated by the issue of merger / acquisition and conglomerates, where a formerly independent company, say, located in Country A, has been acquired by the "parent company", located in Country B, or where because of a merger, the headquarters moves to either Country A or B. These companies may have a unique product line or facilities; an example is Tata Motors' purchase of Jaguar Land Rover (JLR). Tata Motors is based in Mumbai, India and is listed on the Bombay, New York and Indian National stock exchanges. Meanwhile the headquarters of JLR is Coventry, England. It is not clear that all definitions would consider the relocation of supplier / production to UK / JLR in UK as re/back-shoring.

A similar issue is that of companies establishing wholly-owned subsidiaries, where companies have established subsidiary companies in order to cater for "local" markets, for example, Toyota Motor Manufacturing of the UK (TMMU). It's not evident that all definitions consider the relocation of supplier/production to TMMU as re/back-shoring. A problem that is further exacerbated, from a UK perspective, by TMMU having an engine plant in Wales and a car assembly plant in England.

Therefore current definitions do not always adequately deal with the complex structures of multinational companies and conglomerates, and they do not address the manufacturing situation in Wales specifically and UK as a whole. The following definition of re-shoring is proposed: *"The relocation of production or supplier(s) to the country of a key production / assembly location".*

"Key" is a broad definition of the location's importance, either as a major production centre, the sole production location for certain products, or the number of employees. Parent company location is no longer a relevant factor. The proposition overcomes both the merger / acquisition problem and the subsidiary problem.

Such a definition is also easily adapted for near-shoring: *"The relocation of production or supplier(s) to the region / trade area of a key production / assembly location".*

3. Supply Chain Resilience

The concept of resilience is multidisciplinary, arousing interest from both natural and social scientists [19]. As a result of this, definitions of the term resilience range from those found in the domain of engineering and physical sciences that refer to materials being able to return to their original form after undergoing some form of deformation, and the ecological sciences where ecosystems can rebound from a disturbance [20], to those from the domain of social psychology [9] referring to how populations behave in crisis situations. Resilience is considered to be different in nature from traditional risk management in that risk management, through its loop of identify, assess, control and review, is unable to deal with unforeseeable disruptions [20].

Within SCM the concept of resilience has only recently emerged and is defined as being "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed" [7]. In other academic articles, such as Sheffi [21], it has been suggested that the system in question does not in fact move to a new state but rather "bounces back" to the previous state. Ponomarov and Holcomb [9] through their multi-disciplinary studies further defined resilience as "the adaptive capability of the SC to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at desired labels of connectedness and control over structure and function".

Presently there are ongoing discussions within SCM literature regarding how relevant concepts such as leanness, agility, robustness and flexibility are within the context of SC resilience [22]. The survey of literature has revealed that there has been little in the way of work examining the links between re-shoring within the context of resilience. Bailey and De Propris [11] have stated, without detailed explanation or reference to other works, that SC resilience is a factor in the location decision making process. This was then used by the authors in the survey they conducted in [10]. However, in [10] the term "Supply chain resilience security of supply" is used in the UK industry survey which [11] references. Notably academic work in the field of resilience has, in general, considered security to be a feature of resilience as opposed to a being a separate entity [20]. This suggests that there is need for further investigation into the links between re-shoring and resilience.

4. Factors Driving Re-shoring

There have been multiple studies conducted within the past five years within the UK and internationally examining what is driving companies to re-shore their activities [4, 10, 23-27]. These range from academic studies to those conducted for industrial organisations. The survey results gave differing sets and number of

factors ranging from four to over 10. Therefore the top five ranked factors from each survey were selected, and where necessary these were converted into categories with a coarser granularity. The rankings were then replaced by pseudo-scores which were then used to score and rank the responses from the surveys.

The results from the re-ranking of the eight surveys studied are presented in Table 1, the certainty of rank being based on the frequency a factor appears in a survey. Any factors that only occurred once are unranked and appear in Table 2.

Table 1: Ranked factors influencing re-shoring decisions

Rank	Factor	Certainty	Description
1	Quality	High	Issues related to the quality of the products manufactured abroad
2	Cost related issues	High	Costs related to a variety of factors including general costs, transport costs, management costs, exchange rates and overseas wages
3	Flexibility	High	Flexibility of the suppliers and supply chain, including lead times
4	Delivery/logistics issues	Medium	Factors related to the delivery including delivery times, delivery performance (excluding costs)
5	Worker's skills base	Medium	Whether suppliers have sufficiently qualified staff
6	Coordination factors	Low	Factors related to the coordination of an international supply chain
7	Risk	Low	Various risks to supply chain / operations including general risks, and factors such as IP protection

Table 2: Un-ranked factors influencing re-shoring decisions

Factor	Description
Infrastructure	Quality of infrastructure at the off-shore production site
Supply chain resilience and security	Resilience of the supply chain and its security
Security	Supply chain security

5. Resilience Factors

Unlike the comparatively well-established area of re-shoring, the factors influencing the industrial adoption of resilience are not well studied. Recent survey-based literature on resilience has tended to have been focused on what makes, or can make, a supply chain resilient or whether a supply chain is resilient, as in [28-30].

Pettit [20] undertook a comprehensive survey examining academic work in the area of SC resilience; the SC vulnerabilities and capabilities associated with SC resilience up to 2006 were examined. In addition to this focus group surveys were undertaken to identify potential SC vulnerabilities and capabilities. Based upon the outcomes of the focus group studies the vulnerabilities and capabilities have been ranked and are shown in Tables 3 and 4 respectively.

Table 3: Ranked SC vulnerabilities (adapted from [20])

Rank	Factor	Description
=1	Turbulence	Environment characterized by frequent changes in external factors beyond your control
=1	Deliberate threats	Intentional attacks aimed at disrupting operations or causing human or financial harm
3	Connectivity	Degree of interdependence and reliance on outside entities
4	Sensitivity	Importance of carefully controlled conditions for product and process integrity
5	Resource limits	Constraints on output based on availability of the factors of production
=6	External pressures	Influences, not specifically targeting the firm, that create business constraints or barriers
=6	Supplier/customer disruptions	Susceptibility of suppliers and customers to external forces or disruptions

Table 4: Ranked capabilities that enable SC resilience (adapted from [20])

Rank	Factor	Description
=1	Flexibility in order fulfilment	Ability to quickly change outputs or the mode of delivering outputs
2	Flexibility in sourcing	Ability to quickly change inputs or the mode of receiving inputs
3	Organisation	Human resource structures, policies, skills and culture
4	Visibility	Knowledge of the status of operating assets and the environment
=5	Anticipation	Ability to discern potential future events or situations
=5	Recovery	Ability to return to normal operational state rapidly
7	Security	Defence against deliberate intrusion or attack
8	Adaptability	Ability to modify operations in response to challenges or opportunities
9	Capacity	Availability of assets to enable sustained production levels
10	Dispersion	Broad distribution or decentralization of assets

11	Collaboration	Ability to work effectively with other entities for mutual benefit
12	Financial strength	Capacity to absorb fluctuations in cash flow
=13	Market position	Status of a company or its products in specific markets
=13	Efficiency	Capability to produce outputs with minimum resource requirements

6. Linking Resilience to Re-shoring

As mentioned in previous sections the relationship between SC re-shoring and resilience has not been studied in great detail. This section takes the driving factors for re-shoring identified in Section 3 and examines the synergy between them and the attributes of resilience from Section 4.

Quality

Quality, whilst being a significant factor for driving re-shoring as shown in Table 1, seems to play a far less significant role in the literature on resilience of SCs, as evidenced in Tables 3 and 4.

It has been noted that “Single sourcing, where one supplier is responsible for the supply of a specific item or service may be advantageous from a cost and quality management perspective, but is dangerous in terms of resilience” [7]. Similarly several sources, as identified by [20], have acknowledged multiple sourcing as an approach that builds resilience into a SC. This suggests that although quality in its own right might not be perceived to be something that will improve the resilience of a SC the situation where multiple off-shore sources are replaced with one single local supplier in order to achieve a higher level of quality may potentially lead to a negative impact on flexibility and hence resilience of a SC.

However, the focus of Total Quality Management on customer satisfaction, which is measured by an organisation’s ability to meet and exceed expectations [31] suggests that quality is not restricted to just the product itself and that it is also a service issue. Jin [12] stated that global sourcing can have a negative impact on customer service therefore it would not be unreasonable to suggest that re-shoring could improve customer service and satisfaction, and hence quality. Literature on resilience has noted that the long transport distances associated with global sourcing can increase SC disruption [21]. Long distances and manufacturing quality problems can combine to cause SC disruptions, for example if a batch of a product has already been shipped when a quality problem is discovered either a new batch will need to be produced, the product will need to reworked at its destination or the product shipped back upon arrival.

Therefore whilst quality might not have been identified as a capability for improving resilience there is a link in that actions to improve resilience by re-shoring could improve quality from a customer service / satisfaction perspective.

Cost related issues

The existence of the a trade-off between the potentially competing optimisation goals of SC resilience and cost has been acknowledge within literature in the area of SC resilience [7, 8, 21]. The maintenance of safety stocks, additional suppliers, and back-up sites for a manufacturer in order to achieve resilience has a cost associated with it. However, it has also been noted that a lack of resilience has a cost implication due to costs associated with poor customer service level, vulnerability and possible loss of control [7].

As shown in Table 1 the reduction of various costs has been identified as a major driver of the re-shoring effort. Reduction of some costs, such as transport by having a closer supplier, has the potential to mitigate the vulnerability posed by longer transport distances and more resources that increase operational disruption potential [21].

Flexibility

Flexibility is seen as a driver of re-shoring and also as a capability that enhances the resilience of the SC. As shown in Table 4, and by Pettit et al. [20] flexibility is considered to be the main capability that enables resilience. Sheffi [21] stated that "There is significantly more leverage in making SCs flexible than there is in adding redundancy. Flexibility amounts to building organic capabilities that can sense threats and respond to them quickly. Not only does this bolster the resilience of an organization, but it also creates a competitive advantage in the marketplace." As such it is clear to see why flexibility is also considered to be an important driver for re-shoring.

Delivery / logistics issues

In global chains it has been identified that the longer transport distances and more resources involved increase the chance of operational disruption [21]. This suggests that reductions in the distances involved in transport that are associated with the re-shoring of production or supply will decrease the chances of operational disruption, and hence contribute to an improvement in the resilience of a SC by reducing the likelihood of disruption.

Although not specifically mentioned within Table 4 as being a capability for delivering resilience in the SC, delivery / logistics issues have some relation to the vulnerabilities that were identified in Table 3. Turbulence, deliberate threats,

supplier / customer disruptions, and connectivity all have factors that can potentially create delivery and logistics issues. Therefore reducing disruptions through re-shoring should help improve the resilience of a SC.

Workers' skills base

In Table 1 the skills base of employees is identified as a driving factor for re-shoring of supply, while in Table 4 worker's skill base is not explicitly listed. However, Pettit [20] identified human resource factors, such as training and learning, as capabilities that enhance resilience. So re-shoring in order to overcome a skills problem has the potential to help a SC become more resilient.

Coordination factors

Coordination factors, as detailed in Table 1, have no direct equivalent in either Tables 3 or 4. Despite that there is a degree of synergy between coordination factors and the connectivity vulnerabilities identified by Pettit [20], in particular the scale, or extent, of the supply network, reliance on information flow and degree of outsourcing. A large, or heavily outsourced, supply network will make a SC harder to coordinate.

Risk

Risk is not explicitly identified in Tables 3 or 4 as being a resilience factor. However, as stated by Peck [32], something that is "at risk" is something that is vulnerable, therefore the whole of Table 3 can be considered as a list of SC risks which, if addressed, would improve the resilience of a SC.

7. Conclusions

This work has shown that there is a link between the factors that drive companies to re-shore and the capabilities of a resilient SC. Some are evident, such as the importance of flexibility, some less clear. A prime example of this is quality that does not explicitly appear to have a synergy with resilience yet once examined in more detail the links become more apparent. The research has revealed that there is a lack of consistent terminology which is potentially a barrier to clearly identifying the links between re-shoring and resilience.

8. Limitations and future work

This initial conceptual positional paper is a step towards understanding the relationships between re-shoring and resilience, therefore a more detailed study of companies and their attitudes to SC re-shoring and resilience will need to be undertaken. In particular it will need to examine re-shoring and resilience using similar terminology. Addressing a further research question - "Is supply chain

resilience considered when making sourcing location decisions?" – empirical research is being undertaken involving companies located within the UK.

9. Acknowledgements

The authors would like to acknowledge the support of the Advanced Sustainable Manufacturing Technologies (ASTUTE) project, which is part funded from the EU's European Regional Development Fund through the Welsh European Funding Office, in enabling the research upon which this paper is based. Further information on ASTUTE can be found at www.astutewales.com

10. References

1. Ellram, L.M., *Offshoring, Reshoring and the Manufacturing Location Decision.* Journal of Supply Chain Management, 2013. **49**(2): p. 3-5.
2. Kinkel, S., *Trends in production relocation and backshoring activities.* International Journal of Operations & Production Management, 2012. **32**(6): p. 696-720.
3. Gray, J.V., et al., *The reshoring phenomenon: What supply chain academics ought to know and should do.* Journal of Supply Chain Management, 2013. **49**(2): p. 27-33.
4. Kinkel, S. and S. Maloca, *Drivers and antecedents of manufacturing offshoring and backshoring—A German perspective.* Journal of Purchasing and Supply Management, 2009. **15**(3): p. 154-165.
5. FT. *FT500 Ranking 2013*. 2013 [cited 26th November 2014]; Available from: http://www.ft.com/indepth/ft500.
6. BBC. *Britain for Sale?* 2013 [cited 26th November 2014]; Available from: http://www.bbc.co.uk/news/business-25299230.
7. Christopher, M. and H. Peck, *Building the resilient supply chain.* International Journal of Logistics Management, The, 2004. **15**(2): p. 1-14.
8. Sheffi, Y. and J.B. Rice Jr, *A supply chain view of the resilient enterprise.* MIT Sloan Management Review, 2005. **47**(1).
9. Ponomarov, S.Y. and M.C. Holcomb, *Understanding the concept of supply chain resilience.* International Journal of Logistics Management, The, 2009. **20**(1): p. 124-143.
10. SGH-Martineau. *Bringing Manufacturing Back*. 2013 [cited 26th Nov 2013]; Available from: http://www.sghmartineau.com/publication_event/updates/I&M%20Report.pdf.
11. Bailey, D. and L. De Propris, *Manufacturing reshoring and its limits: the UK automotive case.* Cambridge Journal of Regions, Economy and Society, 2014: p. 1752-1378.
12. Jin, B., *Achieving an optimal global versus domestic sourcing balance under demand uncertainty.* International Journal of Operations & Production Management, 2004. **24**(12): p. 1292-1305.
13. Chopra, S., *Designing the distribution network in a supply chain.* Transportation Research Part E: Logistics and Transportation Review, 2003. **39**(2): p. 123-140.
14. Handfield, R.B. and E.L. Nichols, *Supply chain redesign: Transforming supply chains into integrated value systems*. 2002: FT Press.

15. Lee, H.L., *The triple-A supply chain.* Harvard business review, 2004. **82**(10): p. 102-113.
16. Fratocchi, L., et al., *When manufacturing moves back: Concepts and questions.* Journal of Purchasing and Supply Management, 2014. **20**(1): p. 54-59.
17. Holz, R., *An investigation into offshoring and backshoring in the German automotive industry*. 2009, Doctoral Thesis/Dissertation University of Wales, Swansea November, Document.
18. Sirkin, H.L., et al., *US Manufacturing Nears the Tipping Point: Which Industries? Why, and How Much?* 2012.
19. Spiegler, V.L., M.M. Naim, and J. Wikner, *A control engineering approach to the assessment of supply chain resilience.* International Journal of Production Research, 2012. **50**(21): p. 6162-6187.
20. Pettit, T.J., J. Fiksel, and K.L. Croxton, *Ensuring supply chain resilience: development of a conceptual framework.* Journal of Business Logistics, 2010. **31**(1): p. 1-21.
21. Sheffi, Y., *Building a resilient supply chain.* Harvard Business Review Supply Chain Strategy, 2005. **1**(5): p. 1-4.
22. Spall, S., et al., *The Development of a Resilient Global Suppy Chain Strategy During 'Boom and Bust'*, in *19th Annual Logistics Research Network Conference and PhD Workshop*. 2014: Huddersfield, UK.
23. Kinkel, S., *Future and impact of backshoring—Some conclusions from 15 years of research on German practices.* Journal of Purchasing and Supply Management, 2014. **20**(1): p. 63-65.
24. Janssen, M., E. Dorr, and D.P. Sievers, *Reshoring Global Manufacturing: Myths and Realities*. 2012, Amsterdam: The Hackett Group Inc.
25. EEF. *Backing Britain a manufacturing base for the future*. 2014 [cited 26th November 2014.
26. PwC. *Reshoring - a new direction for the UK economy*. 2014 [cited 29th November 2014; Available from: http://www.pwc.co.uk/the-economy/publications/uk-economic-outlook/reshoring-a-new-direction-for-the-uk-economy-ukeo-march14.jhtml.
27. MAS. *MAS Barometer reveals 'Quality, Cost and Delivery' are prime drivers to move production* 2014 [cited 26th November 2014]; Available from: http://www.mymas.org/news/mas-barometer-reveals-quality-cost-and-delivery-are-prime-drivers-to-move-production.
28. Brandon-Jones, E., et al., *A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness.* Journal of Supply Chain Management, 2014. **50**(3): p. 55-73.
29. Pettit, T.J., K.L. Croxton, and J. Fiksel, *Ensuring supply chain resilience: development and implementation of an assessment tool.* Journal of Business Logistics, 2013. **34**(1): p. 46-76.
30. Sarker, S., et al., *Effects of product and supplier criticality on resilience capabilities: An empirical analysis of a global supply chain*. 2014, Department of Industrial Economics and Management, Royal Institute of Technology.
31. Hauser, J.R. and D. Clausing, *The house of quality.* 1988.
32. Peck, H., *Drivers of supply chain vulnerability: an integrated framework.* International Journal of Physical Distribution & Logistics Management, 2005. **35**(4): p. 210-232.